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RESPONSE OF GYPSY MOTH (LEPIDOPTERA: LYMANTRIIDAE) LARVAE TO STICKY BARRIER BANDS ON SIMULATED TREES

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Abstract.—The behavioral response of gypsy moth, *Lymantria dispar* (L.), unfed first instars to intact and defective sticky barrier bands was determined. The barrier bands were installed on simulated trees in a laboratory arena. Defects incorporated into the barrier bands were: gaps in the sticky material (2 mm, 4 mm, and 8 mm width), tunnels under the band (3 mm and 6 mm height) and bridges across the sticky material (cross sections of 1 mm^2 and 2 mm diameter). The defects allowing the highest percentage of larvae to cross were the 2 mm diameter bridge (55.3%) and the 6 mm high tunnel (46.6%). Other defects also allowed crossing. These findings indicate the importance of frequent inspection and repair of sticky barrier bands that are used for gypsy moth control.

Key Words: *Lymantria dispar,* barrier bands, behavior

Sticky barrier bands are used to protect trees against various pests, including the gypsy moth, *Lymantria dispar* (L.). Originally, barrier bands were made by applying sticky substances formulated with materials which included coal tar derivatives and rosin oil. These sticky substances were applied directly to the bark (Burgess 1930, Collins and Hood 1920, Forbush and Fernald 1896). Recently, other types of sticky materials have been applied on top of tape bands on tree boles (Blumenthal 1983, Blumenthal and Hoover 1986, Webb and Boyd 1983). Such barriers are still used by homeowners and managers of small tracts of land (Miller and Lindsay 1993). Success of this method depends upon the ability of the barrier to prevent the return of larvae to the canopy after ballooning or silking down (Burgess 1930, Leonard 1971, McManus 1973). In the field, barrier band efficacy may be reduced by gaps in the sticky material from uneven application, tunnels under the tape caused by texture or contour of the tree bark, and dirt, debris or leaves that become stuck in the material creating bridges. Blumenthal (1983) made useful observations on the response of gypsy moth larvae when they encountered barrier bands, however, these observations were generally of older larvae, and did not include responses to damaged or otherwise compromised bands. Thorpe et al. (1993) found barrier bands reduced larval numbers in groups of trees, but only by about 28%. The present study involved the quantitative analysis of larval response to intact and compromised sticky bands through controlled laboratory experiments. Results lead to a better understanding of possible causes of variable performance of these devices (Blumenthal and Hoover 1986, Thorpe et al. 1993).

Methods

Test arena, bole, and band treatments.—A corrugated cardboard carton was used to form the walls of the arena (60 cm^3) (Fig. 1). The box was lined on the inside with white drawing paper to reduce directional bias due to light sources and extraneous sil-

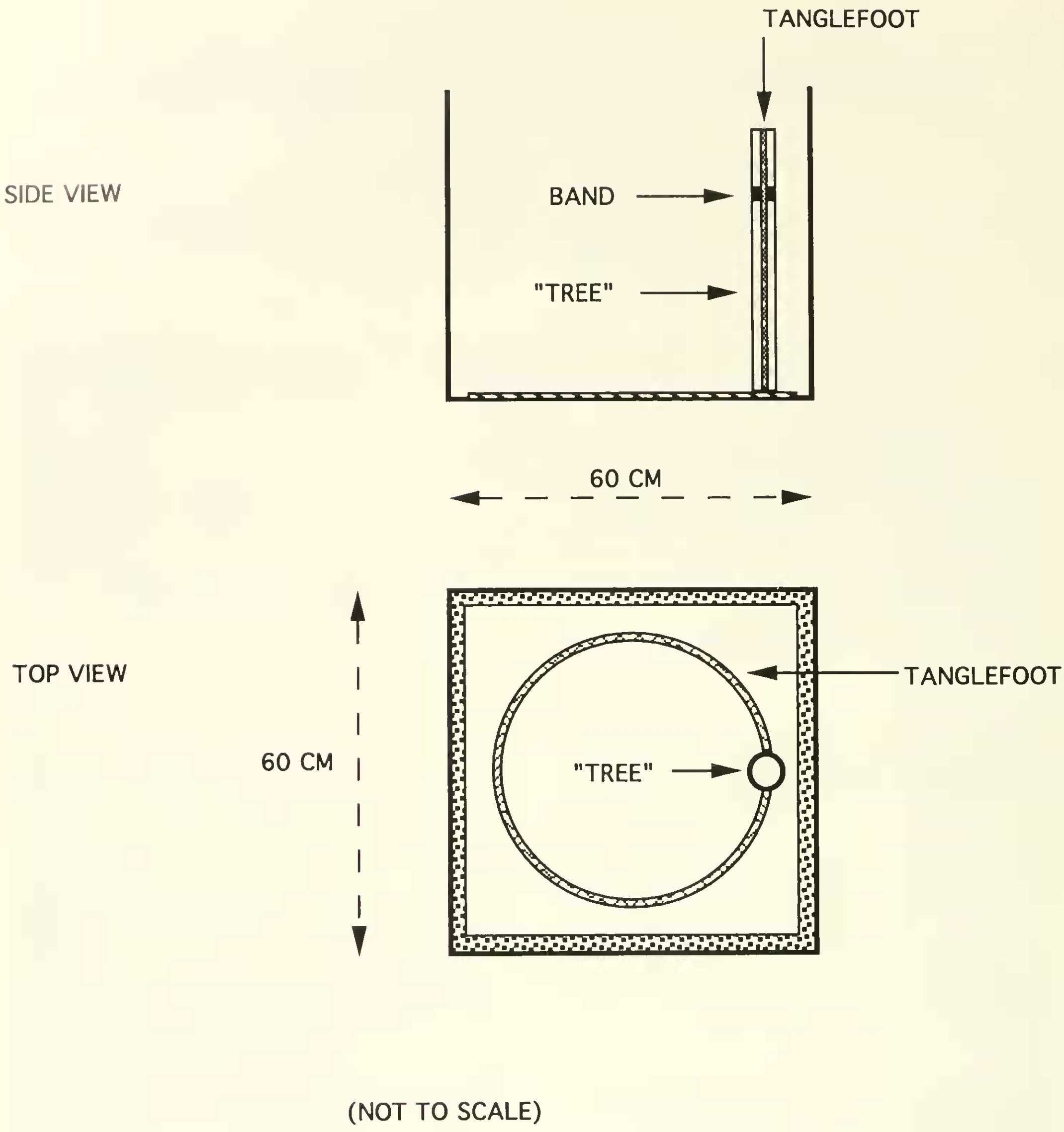

Fig. 1. Test arena with artificial bole ("tree") assembly in place. Graphics were generated with MacDraw II® (Schutter et al. 1988).

houettes, both of which influence larval movements (Ludwig and Schneider-Hempel 1954, Roden et al. 1992, Zanforlin 1970). The simulated bole was constructed of a cardboard mailing tube 92 mm outside diameter and 597 mm height (Alperstein Bros., Inc., Silver Spring, MD). The yellow paper sheathing on the tube was peeled off to expose the unbleached, undyed cardboard. The tube was attached to a corrugated cardboard base (approximately 58 cm^2) by anchoring it with two straight pins and sealing the seam with acrylic latex caulk plus silicone (DAP Inc., Dayton, OH). Caulk was allowed to dry at ambient room temperature and relative humidity for a minimum of 24 hrs. before the apparatus was used for testing. Placement of the artificial bole was approximately 1 cm from the edge of one side and on center relative to that side. A band of Tanglefoot® (Tanglefoot Co., Grand Rapids, MI) was applied in a circle (approximately 50 cm diameter) on the base to prevent larvae from leaving the test arena. This containment band bisected the bole longitudinally so that larvae were restricted to one half of the bole facing the center of the arena. New bole and base assemblies were used for each replicate for each treatment in order to eliminate any possible influence from silk trails and chemical cues from previous tests.

The barrier band was constructed of duct tape (ServiStar®, SSR20340, SERVISTAR Corp., Butler, PA) 5.08 cm wide that was wrapped around the bole with the lower edge of the tape approximately 43 cm from the base. In all treatments, a sticky layer was formed by masking a 1 cm band in the center of the duct tape with Scotch® Magic® Tape (3M Commercial Office Supply Division, St. Paul, MN), applying Tanglefoot along the unmasked area and then smoothing the Tanglefoot with a glass microscope slide to give a thin, uniform layer that was 1 cm wide after removing the tape. All treatments were modifications of this basic configuration (Fig. 2).

Treatments using gaps in the sticky layer were formed by masking with a piece of Magic® Tape of the appropriate size. Three widths of gaps were tested: 2 mm (approximately 2× the width of a first instar head capsule), 4 mm, and 8 mm. Treatments using tunnels were formed by placing a plastic form on the duct tape band and securing it with another layer of duct tape; the Tanglefoot band was then applied on the top layer of duct tape. Two sizes of tunnels were tested. The form for the smaller tunnel (low tunnel) was made from a plastic soda straw that was bisected lengthwise and trimmed to 5.08 cm (duct tape width); the tunnel space was 3 mm wide at the base and 3 mm high at the center. The larger tunnel (high tunnel) was made from a piece cut from a polystyrene container (thickness: 0.3–0.5 mm) and bent to form a tunnel with a base width of 10 mm and center height of 6 mm. Two sizes of bridges were tested. One type (1 mm bridge) was formed from a flat wooden toothpick (Forster Mfg. Co., P.O. Box 657, Wilton, ME) that was trimmed to the dimensions 1.22 ± 0.02 mm × 1.25 ± 0.04 mm × 30 mm. The other bridge (2 mm bridge) was a 30 mm section of a wooden applicator stick (Fisher Brand®, Cat. # 01-340) (diameter: 2.18 ± 0.01 mm). The 1 cm band of Tanglefoot® was sufficient to hold the bridges in place.

Test insects.—Gypsy moth egg masses were provided by the Otis Methods Development Center, US Department of Agriculture, APHIS, Otis ANG, MA. They were from generations F37, F38, and F40 of the New Jersey Standard Strain (NJSS). They were stored at 4°C until three to five days before testing. They were then placed in a sealed plastic bag at ambient room temperature (20–25°C) with moist paper towels to maintain high humidity. Egg masses were checked daily. When the larvae began moving off the egg mass, that egg mass was used for tests. Larvae were introduced to the arena by placing the entire egg mass in the center of the base allowing approximately 50–100 individuals to crawl off (Fig. 1), and then promptly removing the egg mass with the remaining larvae. All test insects were unfed first instars.

Validation of test arena.—A series of preliminary tests were conducted to determine if test insects behaved in the arena in a manner consistent with that described in the literature. Tropism and behavior of larval gypsy moths are well documented (Doan & Leonard 1975, Roden et al. 1992, Weseloh 1990, Zanforlin 1970) and it was desirable to verify that behavior in the arena was similar to that previously reported. A variety of images were presented to larvae in the arena, including a solid black panel covering one side of the arena, both black and white vertical bars on contrasting backgrounds,

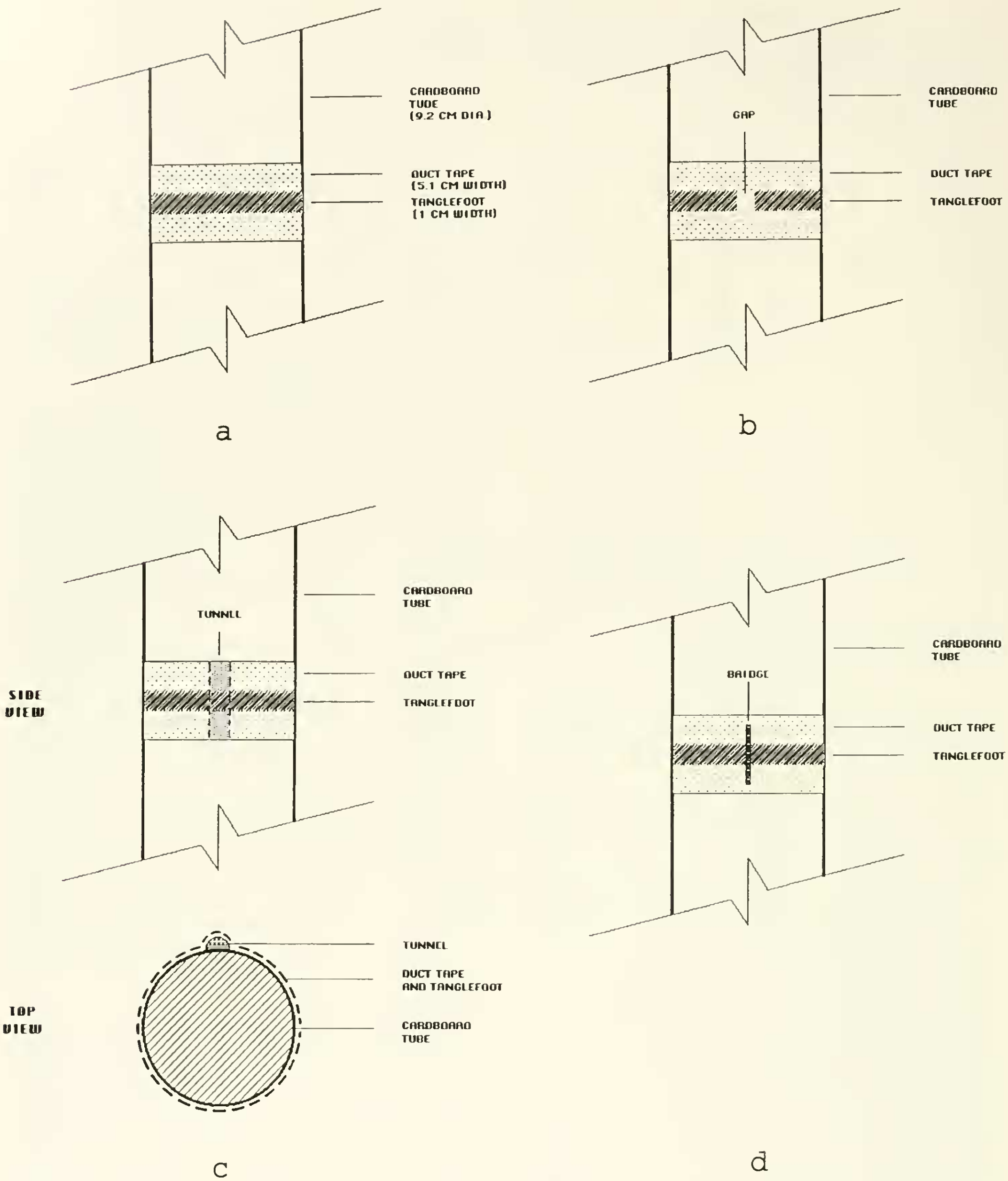

Fig. 2. Barrier band treatments as installed on artificial boles. In the one hour laboratory tests treatments included a) duct tape band with an unbroken sticky layer b) three sizes of gaps tested and c), d) two sizes each for the tunnels and bridges. Graphics were generated with Desk Paint® (Gariepy 1988).

and cardboard mailing tubes of the type later used in the barrier band tests. Groups of 50 to 100 larvae were observed for periods of 30 minutes or longer and their movements were recorded on video tape. The initial observations and later review of the video tapes indicated that the larvae were strongly attracted to black vertical bars of various widths on a white background. This is consistent with earlier reports of this behavior (Roden et al. 1992, Zanforlin 1970). Larvae also readily moved toward and climbed the cardboard mailing tubes placed in the arena.

Barrier band tests.—Tests were conducted for 1 hour, which began at the time that the egg mass was removed from the center of the arena. The test was observed continuously, and every 10 minutes the following information was recorded: number of larvae that crossed the barrier band, total number of larvae on the bole, number that walked back down below barrier band, and number that silked down past the barrier or simply dropped.

The first series of tests consisted of seven treatments: 1) duct tape banding with no Tanglefoot, 2) a barrier band with a continuous band of Tanglefoot, gaps in Tanglefoot of 3) 2 mm, 4) 4 mm, and 5) 8 mm, and the two different sizes of tunnels that were 6) 3 mm and 7) 6 mm high in the center. The second series of tests consisted of four treatments: 1) duct tape without Tanglefoot, 2) and 8 mm gap, and two sizes of bridges that were 3) approximately 1 $mm^2 \times 30$ mm and 4) approximately 2 mm diameter × 30 mm. Each series was analyzed as a Latin Square design, with artificial boles and time periods as separate effects (Cochran and Cox 1957, SAS Institute 1987).

Table 1. Percentage of unfed first instar larvae crossing barrier bands.

Treatment	Series 1	Series 2
Tape only	93.5 a	82.4 a
High tunnel	46.6 b	–
8 mm gap	31.4 c	23.9 c
Low tunnel	5.8 d	–
4 mm gap	2.8 d	–
2 mm gap	0 d	–
Unbroken band of Tanglefoot	0 d	–
2 mm bridge	–	55.3 b
1 mm bridge	–	27.5 c
	(SE = 2.5)	(SE = 5.3)

[1] Numbers within a column followed by the same letter are not significantly different at a 0.05 comparison-wise error rate (LSD test).

Results and Discussion

The percentages of larvae that actually found and climbed on the bole during the 1 hour tests were 87.7% for series 1 and 78.1% for series 2. Analyses indicated no effects of treatment, bole, or time period for finding the bole. Numbers that either walked down or silked down below the barrier band during the test period were very low (typically three or less out of 50–100) and typically occurred in the last 10–20 minutes of the test period; these categories were not statistically analyzed. Notable exceptions occurred in two trials, both control treatments in series 2. In these trials, 28 and 18 larvae moved below the duct tape-only bands by either walking or silking down. We suspect this behavior was promoted, at least in part, by crowding around the top edge of the bole. Apparently many of these larvae re-crossed the band walking upward which resulted in reporting of greater than 100% crossing during the test. Because of this anomaly, these two data points were entered as 100% crossing for purposes of analysis.

The frequency with which larvae were able to cross the band was calculated as a proportion of the numbers that actually found the bole during the tests (Table 1). There were significant treatment effects observed in both series of test (series 1: $F = 194.1$; df = 6,30; $P = 0.0001$; series 2: $F = 26.7$; df = 3,6; $P = 0.0007$). No bole effects were seen in either series. No time effect was seen in series 1, however the time effect was significant in series 2. This may have been due to some environmental factor or difference in handling of the group of egg masses used for tests.

The high tunnel and the 8 mm gap both allowed substantial numbers of larvae to cross the barriers (46.6% and 31.4%, respectively) (Table 1). In contrast, no larvae successfully passed through the 2 mm gap, which, based on measurements of the larvae, is wide enough to allow passage without touching the sticky material. Some larvae were observed entering the 2 mm gap, sometimes as far as half their body length, and then backing out of the gap.

The comparison of bridges and the 8 mm gap indicated that a bridge of approximately 1 mm width reduced the effectiveness of the barrier bands as much as an 8 mm gap in the sticky material (Table 1). Doubling of the bridge width in this test allowed a two-fold increase in the proportion of larvae that crossed the barrier.

Bridges were more detrimental to the efficacy of barrier bands than were gaps and tunnels of similar size, based on those sizes tested in these experiments (Table 1). The 2 mm bridge allowed strikingly more neonates to cross than did the 2 mm gap and the low tunnel. It should be remembered that these test periods were limited to 1 hour. Since more time is available to larvae in the field it is reasonable to expect more individuals to cross bands having defects. This indicates the importance of frequent inspection and repair of these devices to optimize their performance.

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